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Improved Cottonseed Meal For Broiler and Chick Rations

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SUMMARY

Cottonseed meal has long been recognized as an excellent source of protein for cattle and sheep feeds. Because it contains gossypol, a substance in its unmodified state that is toxic to nonruminant animals, the use of meal for poultry and swine rations has been limited. Another characteristic limiting its use has been the variability of protein quality.

Through research, cottonseed meal has been improved. The improved product is low in toxic gossypol, is high in protein quality, and can be used as a protein concentrate in rations for growing poultry.

Scientists are working to improve cottonseed meal even more, so that it can be fed in unrestricted amounts to all classes of animals. With this as a goal, research is continuing.

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IMPROVED COTTONSEED MEAL FOR BROILER AND CHICK RATIONS

Cottonseed meal, a co-product in the crushing of cottonseed to obtain oil, has long been recognized as an excellent protein concentrate for cattle and sheep rations. But two of its characteristics have limited or precluded its use in feeds for poultry:

1. Cottonseed meal contains gossypol, a pigment which is toxic to nonruminants and which may depress growth unless removed or inactivated during processing.

2. Cottonseed meal varies in protein quality according to the conditions to which the cottonseed kernel is subjected during processing. Temperature is particularly important, because excessive heat destroys, or makes unavailable, certain of the essential amino acids of protein.

Gossypol and variable protein quality have prevented cottonseed meal from being used as a major protein ingredient in rations for all classes of poultry.

RESEARCH PROGRESS

Considerable progress has been made toward expanding the area of possible use of cottonseed meal, as the result of a cooperative research program among State agricultural experiment stations, industrial laboratories, the National Cottonseed Products Association, and the Southern Utilization Research and Development Division of the Agricultural Research Service. This research had made possible the production of an improved cottonseed meal, defined as one having low free-gossypol content and high protein quality.

Feeding tests have shown that improved cottonseed meal can be used in rations for growing poultry without ill effects, and that growth and feed efficiency of these rations compare favorably with those containing other vegetable proteins. It is estimated that in 1956 between 250,000 and 500,000 tons of improved cottonseed meal were used in commercial broiler and chick feeds.

Research that culminated in the production of improved cottonseed meal began early in the 1940's. Studies of the chemical and physical properties of cottonseed and of the gossypol-containing pigment glands gave researchers an understanding of the role played by gossypol and laid the groundwork for producing a low-gossypol meal.

Early in the course of these studies, ARS scientists developed a method for removing the gossypol-containing glands from cottonseed kernels. The method was called the flotation process, and although it did not prove commercially feasible, it did make possible the preparation of gossypol-free cottonseed meal for feeding tests.

Continued research showed that gossypol-containing glands could be ruptured during processing, and part of the freed gossypol inactivated or made harmless. It was also found that processing affected protein quality. These findings enabled scientists to launch research specifically designed to inactivate gossypol and to preserve protein quality.

Gossypol Inactivation

Gossypol inactivation became the first major goal of this research. An investigation of processing methods revealed that pressure alone is not as effective in rupturing glands as a shearing action, such as takes place when kernels are forced through a screw press. The investigation also revealed that gossypol released from the glands either remained as free gossypol, i.e., gossypol that could be easily extracted from the meal with solvents, or became bound gossypol, which could not be easily extracted. The amount of free gossypol was known to be associated with toxicity in cottonseed meal and high processing temperatures were found to reduce the toxic free-gossypol content. A study of various processing methods was instituted to determine which methods could be utilized to produce meals low in free gossypol.

Protein Quality

Preservation of protein quality was the second major objective of the research project. Protein quality is a term used by nutritionists to describe the feeding value of ingredients used as protein supplements. A high-quality protein ingredient is defined as one which has readily available, in adequate amounts, all of the 10 amino acids--or building blocks that make up a protein--which are essential to the proper nutrition of nonruminant animals. A low quality protein for nonruminants, on the other hand, is one that lacks adequate quantities of one or more of these essential amino acids. However, ruminants, such as cows, can consume a so-called low quality protein, and utilize it to build tissue. This is possible because microflora exist in the digestive tract of ruminants which help digest the low quality protein, synthesize the missing amino acids, and retain the material in their "bodies" as a high quality protein. A portion of these microflora pass down the animal's digestive tract where they, in turn, are digested. In this manner, ruminants utilize low quality proteins to build

tissue. Since nonruminants lack these microflora, all of the essential amino acids must be readily available in the protein. High quality protein is therefore defined as one containing adequate amounts of all the essential amino acids at the time it is fed.

The cottonseed kernel, before processing, contains all of the essential amino acids in amounts deemed adequate for proper nutrition, although one of these, lysine, may be in borderline supply in a corn-cottonseed meal ration. But overheating during processing reduces the availability of these amino acids to the digestive system, just as it does in the processing of any vegetable protein. Consequently, meal produced by high-temperature processing methods tends to be low in protein quality, and meal produced by low-temperature processing methods tends to be high in protein quality.

Results of the processing research made it obvious that a compromise had to be worked out which would provide the proper temperature and processing conditions to reduce free gossypol without materially lowering protein quality of the cottonseed kernel.

Before these processing conditions could be set up and commercial processing methods evaluated, rapid and accurate methods for checking gossypol content and protein quality had to be devised, and the maximum amounts of free gossypol that could be tolerated by poultry had to be determined.

Analytical Methods

Southern Utilization Research and Development Division chemists developed tests for determining the total gossypol content of cottonseed kernels and meats, the total gossypol content of oil, and the free-gossypol content of meal. The last mentioned, called the aqueous-acetone test, 1/ made possible the rapid evaluation of commercial cottonseed meals on the basis of free-gossypol content and their suitability for use in poultry feeds. The three tests made it possible for the first time to trace the course of gossypol through the processing operation and to evaluate kernels, meal, and oil as to gossypol content.

A completely reliable test for protein quality is still needed, but several methods for estimating protein quality have been devised by cooperating groups. The one most frequently used is the nitrogen solubility method, which is a measure of heat damage. It provides a rough means of checking protein quality.

1/ The test has been adopted by the American Oil Chemists Society and the Association of American Feed Control Officials.

Maximum Safe Dietary Level of Free Gossypol

Development of analytical methods made the job of determining the safe dietary level of free gossypol 2/ easier. This level was determined by feeding baby chicks diets containing different amounts of free gossypol. The diets were constructed by blending various meals to achieve the proper concentration of free gossypol, or by adding to a gland-free meal, prepared by the flotation process, various amounts of extracted gossypol. Results of the feeding tests established 0.016 percent free gossypol as the maximum level that could be included in the total diet for starting and growing poultry without harmful effects.

No more than 40 pounds of a 41-percent-protein cottonseed meal is required to prepare a 100-pound bag of feed analyzing 20 percent protein. If the cottonseed meal contains 0.04 percent free gossypol, the 100-pound bag of feed will analyze 0.016 percent free gossypol, the safe dietary level. Fixing 0.04 percent as the maximum free-gossypol content of improved cottonseed meal provides an adequate safety factor, since less than 40 pounds of 41-percent-protein meal is actually required to produce a 100-pound bag of 20-percent protein feed--the other ingredients used in the feed also furnish protein.

Determination of Processing Conditions

The next objective of research was the determination of processing conditions for the production of improved cottonseed meal. Once tests had been devised to trace the course of gossypol through the processing operation, and the safe level of free gossypol determined, researchers were in a position to determine the range of operating conditions that would yield low-gossypol, high-quality cottonseed meal.

There are several methods of processing cottonseed kernels to remove the oil. In general, all of the methods include four steps:

1. Removal of hulls and linters from the cottonseed kernel.
2. Preparation of the cottonseed meats to make oil removal possible.
3. Extraction of the oil from the meats.
4. Filtration of the oil and conditioning of the meal.

All four steps influence meal quality. Step 1 largely determines the protein content of the meal. Steps 2 and 3, which include cooking, determine free-gossypol content and affect protein quality. Step 4 determines texture and palatability of the meal.

2/ A knowledge of the safe dietary level of free gossypol is important since it is known that free gossypol, rather than bound, is associated with toxicity or inhibition of growth.

The most commonly used methods--hydraulic press, screw press, and solvent extraction--were studied and the meal evaluated according to free-gossypol content and protein quality.

Hydraulic Press

Cottonseed meal produced by the hydraulic press method usually contains more than 0.04 percent free gossypol, but some hydraulic-pressed meals contain only a little more than this amount. Almost all hydraulic-pressed meals possess a high level of protein quality.

Screw Press

Screw-pressed meals in general have a free-gossypol level ranging in the neighborhood of 0.04 percent. Protein quality varies greatly with the conditions of cooking and pressing and usually is not as high as that of hydraulic-pressed meals. In many instances the energy involved in pushing the material through the press is so great as to create considerable heat damage.

Solvent Extraction

Solvent-extracted meals may be produced by either of two processes: direct-solvent extraction or screw-press-solvent extraction.

Direct-solvent extraction produces a meal that usually contains more than 0.04 percent free gossypol and possesses a high level of protein quality. Filtration-extraction, a variation of the direct solvent process developed by ARS engineers, produces a meal below the established maximum free-gossypol level.

Screw-press-solvent extraction is a combination of the screw press and direct solvent methods and combines the advantages of these two methods to a considerable degree. The meal is lower in free gossypol than that produced by direct solvent extraction and higher in protein quality than that produced by screw pressing alone. If all the steps in processing are carefully controlled, improved cottonseed meal can be readily produced by this combined method.

Scientists concluded that the use of any one method does not assure a definite free-gossypol content or protein-quality level, and that careful control of processing conditions is necessary, in all methods, to produce improved cottonseed meal. They were able, however, to define a range of processing conditions for the production of improved meal, and this has been provided cottonseed processors interested in producing a meal for poultry feeding.

Testing Improved Cottonseed Meal

To gain information regarding the performance of improved cottonseed meal in mixtures with soybean oil meal, ARS provided cooperating laboratories with cottonseed meals varying in gossypol content and protein quality for use in feeding tests. Nutritional data obtained by these laboratories were presented at the Third and Fourth Conferences on Cottonseed Processing as Related to the Nutritive Value of the Meal held at New Orleans in 1953 and 1957, respectively. The most recent data, covering 28 different diets and 9 commercial cottonseed meals, are being subjected to complete statistical analysis before conclusions are drawn regarding the relationship between processes, processing conditions, chemical properties, and nutritive performance of the meals for broiler growth. However, the following statement regarding the use of improved cottonseed meal was made at the Third Conference:

> "Results presented thus far indicate that chick and broiler rations containing cottonseed meal and soybean meal in equal proportions on a nitrogen basis are equal or superior to rations based on either cottonseed meal or soybean alone, where the cottonseed meal has 0.04 percent or less of free gossypol and 75 percent or more of nitrogen solubility in 0.02 N NaOH solution."

At the Fourth Conference the following supplementary statement was made:

> "The committee reaffirmed the validity of the statement on cottonseed meal made at the Third Conference on Cottonseed Processing as Related to the Nutritive Value of the Meal held in New Orleans, November 1953.
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> "The committee feels that there is evidence that there exist cottonseed meals of 0.04 percent free gossypol but with less than 75 percent nitrogen solubility, which when substituted for 50 percent of the soybean meal in a practical broiler ration, give excellent performance. The committee feels, however, that it should be the objective of cottonseed processors, when preparing meals for broiler rations, to retain the maximum quantity of desirable nutrients insofar as possible. It is the general experience that with any given process, higher nitrogen solubility generally reflects less damage to or less destruction of desirable nutrients."

Summary of Achievements

Research achievements of the program to date can be summarized as follows:

1. Analytical methods for determining gossypol content and for estimating protein quality were devised.

2. The maximum safe level of free gossypol in diets growing poultry was fixed at 0.016 percent.

3. A range of processing conditions were determined which minimize damage to protein quality and limit free-gossypol content of cottonseed meal. Usually the desired free-gossypol content can be achieved by a process involving screw pressing. The desired protein quality can also be achieved by screw pressing. Today processors have a better understanding than ever before of conditions necessary to produce improved meal, and an increasing volume of cottonseed meal suitable for use in nonruminant feeds is available.

4. Feeding tests indicated that growth and feed efficiency of chick and broiler rations containing equal amounts of improved cottonseed and soybean meals are equal or superior to rations based on either vegetable protein alone.

As a result of these achievements, improved cottonseed meal is being used in mixed feeds for broilers and growing chickens with satisfactory results.

CONTINUING RESEARCH

Achievements to date do not complete the research program. Southern Utilization Research and Development Division scientists are still able to produce a meal in the laboratory of higher protein quality than that produced commercially. Research engineers are still working to improve existing oilseed extraction processes and to devise new ones that will preserve the original protein quality of the cottonseed kernel. Analytical chemists are endeavoring to perfect a rapid, accurate test for the determination of free gossypol in manufactured feeds. All groups are pooling their efforts to work out problems in connection with the feeding of cottonseed meal to swine, laying hens, and calves.

Swine are nonruminants and are affected by free gossypol and low protein quality in much the same manner as poultry, but apparently do not have as high a tolerance for free gossypol. Swine feeding tests using cottonseed meal have been run at various State agricultural experiment stations and at the ARS Agricultural Research Center, Beltsville, Md. Under certain conditions, researchers have found 0.007 percent free gossypol a toxic level in the total diet of very young pigs. Under other conditions, no toxic effects developed when the level was raised to 0.024 percent. It is probable that 20 percent of the diet for pigs over 8 weeks of age can be made up of improved cottonseed meal.

It has been discovered recently that the amount of total protein provided swine--and the quality of that protein--has a bearing on their tolerance for free gossypol. However, more research is needed to fix the maximum limit of free-gossypol consumption and the other dietary factors surrounding its safe usage.

Tests using cottonseed meal for laying hens have been run by State agricultural experiment stations and the ARS Southwest Poultry Experiment Station, Glendale, Ariz. When free-gossypol levels of 0.012 percent of the total diet were fed laying hens at Glendale, albumen and yolk discoloration resulted. But egg production, hatchability, feed consumption, body weight, and livability were not adversely affected. There was no mortality when the dietary level was raised to 0.025 percent. Albumen and yolk color were still affected, however, when the dietary level was dropped to 0.001 percent. Eggs placed in cold storage showed yolk discoloration after 3 days, and albumen turned pink as storage periods lengthened. Work is continuing to produce a cottonseed meal that can be fed to laying hens without affecting this aspect of egg quality.

A very limited amount of work has been done in connection with feeding cottonseed meal to calves. Although cows can be fed unrestricted amounts of high-gossypol cottonseed meal, calves cannot because the rumen of the young calf has not developed sufficiently to convert gossypol into a nontoxic form. The North Carolina Agricultural Experiment Station has reported tests with calves fed a diet containing 40-percent low-gossypol cottonseed meal. No toxic effects were observed during the 6 months of the test. The use of cottonseed meal in milk substitutes for calves is being investigated by several research groups.

Research will continue along all of these lines. The high degree of cooperation between the State agricultural experiment stations, oilseed processors, feed manufacturers, the National Cottonseed Products Association, and the U.S. Department of Agriculture leads one ARS researcher to say, "We are looking forward to the day when cottonseed meal can be fed in unrestricted amounts to all classes of animals and poultry, when protein is of the highest possible quality, and when the product possesses great uniformity."

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